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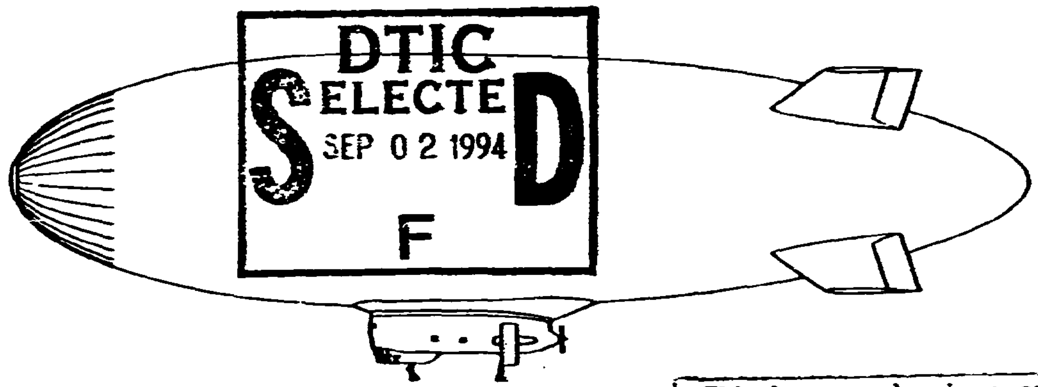

Airship Applications of Modern Flight Test Techniques

by

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BACKGROUND

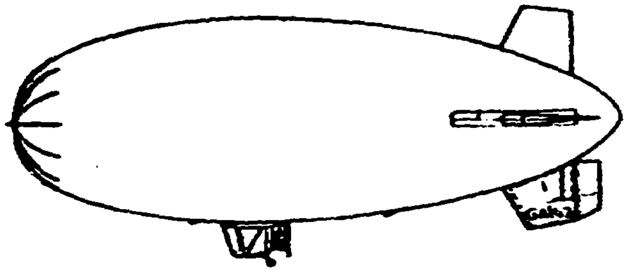
- Naval Air - 1917-1963
- 30 year hiatus
- Changing times
- Recent DOD experience

PURPOSE

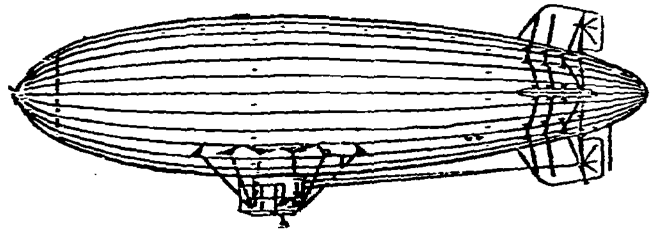
- Experience with airships
- Develop LTA test methods
- Design considerations

SCOPE - AIRSHIPS FLOWN

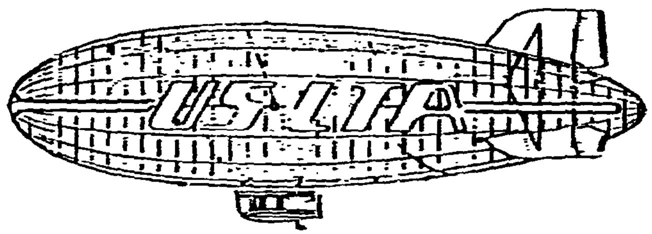
Total time: 19.7 flight hours



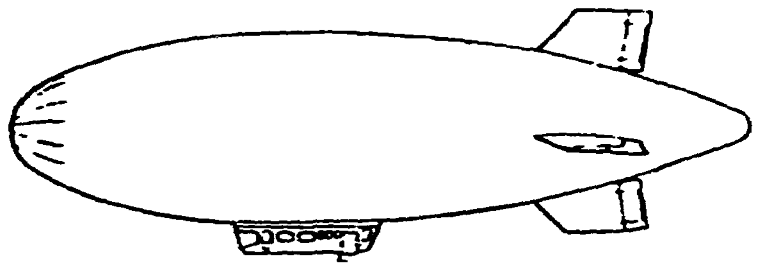
GA-42
42,000 cu. ft.
90' long
TOGW 1,200 lbs.



A-60+
68,000 cu. ft.
128' long
TOGW 4,400 lbs.



USLTA 138S
138,000 cu. ft.
160' long
TOGW 9,300 lbs



Skyship 500 HL
235,000 cu. ft.
194' long
TOGW 12,600 lbs.

SCOPE - BASIC PRINCIPLES

- Aerostatics
- Aerostatic flight controls
- Flying qualities of design

SCOPE - MISSION TASKS

- Launch & recovery
- Transit
- AEW/ASW/law enforcement patrol
- Underway replenishment

METHOD OF TEST

- Cockpit evaluation
- Ground handling
- Performance
- Flight control system characteristics
- Longitudinal flying qualities
  - Short period
  - "Phugoid" caused by ballonets
  - Representative mission tasks
- Directional flying qualities
  - Directional period (like short period)
  - Directional stability (like spiral mode)
  - Representative mission tasks

R & D - COCKPIT EVALUATION

- Test method
  - * Conventional methods apply
- Observations
  - * No conventions on layout
  - * Layouts often very poor
- Design considerations
  - * Better human factors in cockpit design

R & D - Ground Handling

- Test Method
  - Totally new - ground crew test
  - WX big variable
  - Coarse requirements - no fine tasks
- Observations
  - Ground crew's job
  - Pilot can help little
  - Crew size variables
- Design considerations
  - Excellent low-speed maneuvering capability
  - Ballast adjustment system

R & D - PERFORMANCE

- Test Method
  - * Conventional for T/O, landing, climb/descent
  - * USAFTPS for range & endurance
  - * Turn perf initially tested conventionally
- Observations
  - * WX crucial, must test in smooth air
  - * No sustained turn perf on 3 airships
  - * Instantaneous turn perf tied into dynamics
  - * Had to develop new turn perf test method
- Design considerations
  - * Endurance tied to WX
  - * Top speed

R & D - FLIGHT CONTROL SYSTEM

- Test methods
  - * Observation
  - * Mech. char. testing requires good WX, instrumentation if possible
- Observations
  - * Two fully reversible, one hydraulicly boosted, one fly-by-wire
  - * Fully reversible systems had either excessive control deflections or high control forces
  - * Irreversible systems did not have feel systems of any type
  - * Pressure systems often confusing to operate, could not command trim directly
  - * In two-ballonet airships, ballonet trim authority was greater than elevator pitch authority
  - * Control power varies with airspeed
- Design considerations
  - * Displacements
  - * Forces
  - * Improve low speed control power

R & D - LONGITUDINAL FLYING QUALITIES

- Test method
  - * Conventional dynamic tests
  - * Modified long stab tests
- Observations
  - * No ∂V with altitude
  - * No Fs/Nz
  - * Short period slow, may need computer-generated inputs for a frequency sweep
  - * Turbulence affects FQ greatly
  - * No phugoid of any sort
  - * In low-moderate turbulence, could do mission tasks fairly easily
- Design considerations
  - * Irreversible FCS very useful
  - * Vectored thrust good for low-speed hover

R & D - DIRECTIONAL FLYING QUALITIES

- Test methods
  - * Similar to longitudinal FQ testing
- Observations
  - * Directional mode sluggish but predictable, took about 45° to build to max turn rate of about 10°/sec
  - * Unstable directionally - would settle into a constant turn if unattended
  - * Turbulence affects strongly
  - * In low-moderate turbulence, could perform mission tasks fairly easily
- Design considerations
  - * Irreversible FCS very useful
  - * Control power at low speed and directional instability requires augmentation for low speed maneuverability

C & R - GENERAL

- Experience gained
- Develop test methods
  * Basic scientific observation works
  * Most methods did not work or did not apply
  * Performance and dynamic FQ tests worked
  * Stability tests did not work
  * Need to refine stability, pressure system test methods
  * Need to test an airship with both irreversible FCS & vectored thrust
- Design considerations
  * Huge area for improvement
  * Missions need clarification
  * Need operator input to design
- Other
  * Would be a good TPS qual eval

C & R - DESIGN CONSIDERATIONS

- Low susceptability to turbulence
- Improved low-speed directional control (bow thrusters?)
- Low FCS forces/good mechanical characteristics
- Autopilot
- Automatic pressure control
- Separate pressure and trim control
- Cockpit layout

Slide #: 1
Title: Title
Narration: Good afternoon. I'm Mike Mcdaniel, and this is LT Sean Brennan. We're here to discuss the application of modern flight test techniques to airships.

Slide #: 2
Title: Background
Narration: From 1917 to 1963, the Navy used airships for airborne early warning and antisubmarine warfare. However, the Navy ceased airship operations in 1963. During the last decade, though, the growth of the sea-skimming antiship missile threat and reduced budgets has led DOD to reexamine the potential of airships to meet modern security needs. Until recently, almost all DOD experience had been with the Airship Industries Skyship 500/600 series airships. Also, there were no documented test methods. This was not adequate for a safe and productive test program.

Slide #: 3
Title: Purpose
Narration: As a result, NAWCAD decided to draft a preliminary airship test manual and test it on several commercial airships. The intent of this program was to build up experience with a range of airship types, develop airship test methods, and gather data on design considerations for operational vehicles.

Slide #: 4
Title: Scope - Airships Flown
Narration: Four airships were flown for a total of 19.7 flight hours. The airships ranged in size from 90 to 200 feet, and in gross weight from 1,200 to 12,000 lbs. Single and twin-engine airships were flown.

Slide #: 5
Title: Scope - Basic Principles
Narration: Testing an airship requires that the different basic principles of an airship be accomodated in test planning.

First, an airship uses aerostatics rather than aerodynamics for most of its lift. Lift is therefore only slightly a function of speed or power, and gross weight, as such, drops out of performance equations.

Second, an airship has a set of pressure controls to regulate envelope pressure. These usually consist of two air bags, called ballonets, inside the main envelope, with pressure trunks to feed air into the ballonets, and valves to let air out. The pressure control system also serves as the trim system for the airship.

Finally, an airship has unusual flying qualities, particularly directionally. An airplane or helicopter usually turns by rolling, using the horizontal component of the lift vector to turn the aircraft. An airship turns by generating a direct sideforce, and any roll motion is purely a nuisance mode.

As a result, airships require some very unusual test methods.

Slide #: 6
Title: Scope - Mission Tasks
Narration: Test planning begins with the mission tasks. Mission tasks for a military airship are fairly straightforward. Launch and recovery, transit, and patrol are self-explanatory. Underway replenishment is a technique for extending an airship's endurance, and calls for refueling and resupplying the airship from a surface combatant or a ground station. UNREP is generally considered to be the most demanding of all airship mission tasks.

enclosure (3)

Slide #: 7
Title: Method of Test
Narration: Our test method was based on conventional USNTPS practice, but required substantial changes. We went back to the basic theories on which all flight testing is based and derived new flight principles, and then developed from these what we thought were appropriate test methods.

On each airship, we did a cockpit evaluation, observed ground handling, tested performance, flight control systems characteristics, longitudinal and directional flying qualities. It is noteworthy that in theory, an airship has no true phugoid, but does have a false phugoid generated by the pressure system. Likewise, an airship has a directional period in the yaw axis that is similar to the short period. Since most airships are directionally unstable, a test similar to the fixed-wing spiral mode test had to be developed to quantify the degree of instability.

It must be understood that the primary objective of these tests were to evaluate the test techniques. What we learned about the characteristics of these airships were merely an interating side effect.

Slide #: 8
Title: R&D - Cockpit Evaluation
Narration: We found that conventional test methods worked well for cockpit evaluations. The four airships examined each had radically different layouts, and all of them had significant problems. Major flight controls, most notably the pressure system controls, were at the limits of the pilot's functional reach. Future designs need to pay more attention to human factors and pilot inputs.

Slide #: 9
Title: R&D - Ground Handling
Narration: Ground handling of an airship has no real parallels in heavier-than-air practice. We observed and participated in ground handling operations, and found that unlike taxiing, the ground handling of an airship is almost entirely the job of the ground crew. The pilot is a passenger, and the airship moves under the direction of the ground crew chief. We observed that weather is a major variable, and that ground crew size also affects workload. For future designs, it appeared that improved low-speed maneuvering capability would let the pilot help the ground crew. We also noted that the current system of loading shot bags onto the airship to adjust ballast could stand improvement.

Slide #: 10
Title: R&D - Performance
Narration: Performance testing, with the exception of turn performance, could be tested with modified versions of existing test methods. USNTPS test methods were satisfactory for takeoff, landing, climb, and descent performance, while USAFTPS test methods for testing reciprocating engines were adequate for range and endurance. The major modification required was to use static heaviness in lieu of gross weight, and to ensure that the tests are performed in the smoothest possible air.

Turn performance, on the other hand, had to be tested in a radically different manner. Three of the four airships tested had no sustained turn performance, while the turn rate acceleration times meant that instantaneous turn performance was a factor of dynamics rather than a performance issue. The only way to realistically evaluate turn performance is to do a time history of turn rate for differing rudder deflections.

The major design considerations are to ensure that the top speed is adequate to cope with weather, and to recognize that endurance will be a function of speed.

Slide #: 11
Title: R&D - Flight Control System

Narration: Flight control system testing showed a wide range of characteristics. Conventional test methods were effective, but required good weather for quantitative data.

The four airships examined included two fully reversible control systems, one hydraulically boosted system, and one fly-by-wire system. The fully reversible systems exhibited either large control deflections or high control forces. The irreversible systems did not incorporate feel systems.

The pressure system controls were confusing to operate, and trim could not be commanded except by opening one ballonet valve and venting air into the other ballonet to force air out. This was particularly important because the ballonet trim authority usually exceeded the pitch authority from the elevators.

Design considerations include improving mechanical characteristics and low-speed control power, particularly in the directional axis.

Slide #: 12
Title: R&D - Longitudinal Flying Qualities
Narration: Longitudinal flying qualities testing required highly modified stability tests, as well as fairly orthodox dynamic tests.

Since an airship cannot generate significant G forces, measures such as stick force per G are meaningless. Also, there was no phugoid of any sort. As a result, the conventional stability measurements did not apply.

Dynamically, the airships all displayed slow short periods. A proper frequency sweep would require a computer-generated input. Turbulence affected flying qualities enormously, and high turbulence would degrade handling qualities by two or three HQRs.

Despite these characteristics, the airships demonstrated good flying qualities in low to moderate turbulence. It was fairly easy to maintain altitude, even during simulated landing approaches.

Future design considerations would include requiring an irreversible flight control system, which reduced pilot workload dramatically. If hovering is required, vectored thrust is essential as well.

Slide #: 13
Title: R&D - Directional Flying Qualities
Narration: Testing of directional flying qualities was conducted in a way similar to longitudinal flying qualities tests. The directional mode was sluggish but predictable, and required about four to six seconds to reach maximum turn rates. The airships were unstable directionally, and would settle into a steady turn if left unattended. As with longitudinal flying qualities, turbulence dramatically affected directional flying qualities. However, the airships all displayed fairly good directional handling qualities in low turbulence. It was possible to perform precision tracking during simulated landing approaches with great accuracy.

Design considerations for the future would include an irreversible flight control system, to reduce pilot fatigue, and augmenting control power at low speeds to aid in landing. A bow thruster system may prove useful for this.

Slide #: 14
Title: C&R - General
Narration: The result of this evolution was that we gained useful experience with a range of airship types. We found that while the basic scientific test method taught at TPS works, many of the conventional test methods did not work on airships. In particular, new methods had to be developed for some dynamics and most stability characteristics. Further work is needed to refine stability and pressure system test techniques. Also, our testing indicated that irreversible flight control systems and vectored thrust both enhance flying qualities, and we recommend further testing on an airship which incorporates both features. For the record, we hope to have a written test manual ready this summer.

As far as general design considerations go, we saw a lot of room for technical improvement in many areas. Above all, we saw a need for operator input into the design, as many of the airship features appeared to be designed to simplify design rather than ease the pilot's job.

Finally, we think that any of the airships tested would make an excellent qual eval for TPS students, because of their unique qualities.

Slide #: 15

Title: C&R - Design Considerations

Narration: We saw several specific areas which we thought needed improvement.

First, any military airship must be designed to minimize turbulence effects, due to the effect these can have on flying qualities.

Second, there is a desperate need for better low-speed directional control to aid in landing and UNREP. Bow thrusters may aid in this.

Third, a flight control system with good mechanical characteristics is needed to aid in predictability of response.

Fourth, an airship desperately needs an autopilot, since cruising flight is very dull in good weather.

Fifth, there is a need for an automatic pressure control system to reduce pilot workload. We found that in protracted climbs and descents, or in turbulence, the pilot had to spend half his time wrestling with the airship and the other half working pressure system controls.

Sixth, there is a need to separate pressure regulation from trim control. Trimming the airship is vital to maintaining pitch authority, reducing control forces, and minimizing drag. Today, this is a complex process requiring that the pilot operate valve and damper controls for both ballonets. It should be possible to either automate this process or adopt a separate air trunk between the forward and aft ballonet. Either would simplify things dramatically.

Finally, there is a need for a more user-friendly cockpit layout. Many of the cockpits we saw during this exercise were poorly designed.

We will now show a video, and then answer any questions you might have.